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Research on AHP-EW Based Comprehensive Capacity Evaluation of Electricity Selling Companies

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***Abstract*—The reform of the electric power system makes a large number of power selling companies enter the electric power market, and the increase of the number of power selling entities also increases the market competition. Therefore, only by improving their comprehensive capacity can power selling companies develop in the changing electric power market in the long run. Therefore, this paper first constructs the comprehensive capacity evaluation index system of power selling companies, then uses the combination weighting method combining the analytic hierarchy process and entropy weight method to calculate the weight of the evaluation index, and finally uses the data of ten power selling companies for example analysis, combines expert scoring and index weight to calculate the comprehensive score of power selling companies and puts forward suggestions for the long-term development of power selling companies.**

Keywords—power sales company; comprehensive capability evaluation; analytic hierarchy process; entropy weight method

I. INTRODUCTION

The further deepening of the reform of the electricity sales side affects the future development plan of the electricity sales company, which is both an opportunity for development and growth, and a challenge to participate in fierce market competition[1]. Due to the injection of social capital, the power sales business will inevitably experience a new pattern of diversified demand and accurate value-added services. Corresponding power sales companies need to explore ways to improve their comprehensive capabilities in order to obtain stable customer sources and relatively superior market competitiveness[2].

At present, domestic and foreign scholars believe that improving the comprehensive capacity of power sales companies needs to start from three aspects: improving the credit level, profitability and marketing ability [3-5]. In terms of improving the credit level, some scholars have proposed to improve the credit level of power sales companies by building a multi-level credit risk indicator system and using a variety of evaluation methods[6-7]. In terms of improving profitability, some scholars mainly study the influencing factors and profit model of profitability, so as to provide a reference direction for power sales companies to improve profitability[8-9]. In terms of marketing capability, the research mainly focuses on the marketing strategy of power sales companies, aiming to pave the way for improving profitability[10-11]. Although the above research has improved the comprehensive capacity of the power sales company to a certain extent, it only starts from a single factor and cannot reflect the comprehensive capacity of the power sales company. Moreover, the above considerations are relatively simple. In the power market, the service capacity and technical capacity can also reflect the comprehensive capacity of power selling companies to a certain extent. Therefore, on the basis of the above research, this paper excavates the influencing factors of power selling companies, constructs a comprehensive hierarchical structure system of influencing factors, and uses the analytic hierarchy process to determine the development direction that power selling companies should focus on.

II. CONSTRUCTION OF EVALUATION INDICATORS

The power selling company carries out the business of purchasing and selling electricity in the electricity market. It undertakes the task of promoting the process of electricity marketization, playing the role of price guidance, and creating an efficient and dynamic electricity market. Under the competitive situation, it is necessary to build a reasonable indicator system to improve the comprehensive capacity of power sales companies and provide optimal choices for power users. Scientific, systematic, practical

Based on the principles of combination of qualitative and quantitative analysis and dynamic characteristics, this paper summarizes and puts forward the evaluation index system of comprehensive capacity of power selling companies.

With the comprehensive capability evaluation of the power sales company as the target level, and the service capability, credit level, technical capability, marketing capability and innovation capability as the first level indicators, the first level indicators will be further subdivided into more second level indicators in consideration of the enterprise development, trading behavior and financial status of the power sales company under each first level indicator, fully reflecting the systematicness and hierarchy of the construction of comprehensive capability evaluation indicators. At the same time, there are also characteristics of mutual connection and restriction among indicators. TABLE Ⅰ shows the specific hierarchical relationship of the indicator

system with 25 comprehensive capacity evaluation indicators in 5 layers.

TABLE I. COMPREHENSIVE CAPACITY EVALUATION INDEX SYSTEM of POWER SALES COMPANY

Target layer	***Criterion layer***	***Factor layer***
Comprehensive capacity of power sales company	Service capability	User satisfaction
		User trust
		Business handling ability
		Failure repair ability
		value added service
	Credit level	credit record
		Completion of the qualification
		certificate
		Compliance with the trading
		rules
		Corporate credit
		Timeliness of contract
		settlement
	Marketing ability	risk control ability
		Procurement cost control ability
		User responsiveness
		Demand-side management capabilities
		market share
		Market development ability
	innovation ability	research and development ability
		Patents and technology ownership volume
		Develop new technologies
		The number of cooperative scientific research institutions or universities

Service capability: The service capability of the power sales company is mainly reflected in that the power sales company can provide users with satisfactory "products". For users, on the one hand, the high-quality service provided by the power sales company can speed up the efficiency of users and save users' time, on the other hand, it can enhance customers' awareness and satisfaction. Therefore, five secondary indicators, user satisfaction, user trust, business handling ability, fault repair ability and value-added service, are selected to evaluate the service ability of the power sales company.

Credit level: The credit of the power selling company refers to the enterprise credit in a broad sense, that is, the trust obtained by the power selling company in the performance of the contract in the power industry payment, cooperation mode and other matters related to the power industry. The credit level of the power selling company will directly affect the operating efficiency of the power selling company. The higher its credit level, the more business opportunities it will obtain. Therefore, credit records, completeness of qualification certificates, compliance with transaction rules, corporate credit and timeliness of contract settlement are selected to reflect the credit level of the power selling company.

Technical capacity: the technical capacity of the power selling company mainly refers to the company's technical integration capacity, value-added service development capacity, rationality of electricity price setting, load forecasting capacity and line loss rate. The technical level directly reflects the comprehensive capacity of the power sales company. That is, the higher the technical capacity of the power sales company is, the more products it can provide meet the needs of users, and the higher its comprehensive capacity is.

Marketing ability: With the in-depth development of the power system reform, the power marketing activities have become an important economic activity of the power selling companies. The lag of marketing work will make the electricity purchased by power grid enterprises and power selling companies from power generation enterprises need to be stored, resulting in waste and increasing the operating costs of enterprises. The marketing ability of the power selling company mainly refers to risk control ability, procurement cost control ability, user responsiveness, demand-side management ability, market share and market development ability.

Innovation ability: The innovation ability of the power selling company is a very important part of its comprehensive ability. The level of innovation ability directly reflects the development potential of the power selling company. Specifically, the higher the innovation capability, the more timely the power sales company can adjust its R&D direction in the reform of the power market, grasp the market development trend, and make itself survive in the changing power market in the long run. The innovation capability of the power sales company mainly includes the R&D strength, the number of patents and technologies owned by the power sales company, the number of new technologies developed, and the number of cooperative scientific research institutions or universities.

III. COMBINATION WEIGHTING EVALUATION MODEL BASED ON AHP-EW

A. Subjective Weighting Evaluation Model Based on Analytic Hierarchy Process

1)Build a hierarchical analysis structure model consisting of target layer, criterion layer and scheme layer

According to the factors that may be involved in the target problem analysis, based on the internal relationship of these factors, a ladder like hierarchical structure is designed and constructed to connect the factors. From high to low, it is the target layer, the criterion layer and the scheme layer.

2)Build Judgment Matrix

According to the constructed hierarchical structure, the target element is recorded as B and its related influencing

factors C1, C2, C3,..., Cn have a dominant relationship. Next, these factors are compared in pairs to further explore the impact of each indicator factor Pi on Pj. Then, the number 1~9 and its reciprocal are selected as the scale to measure the impact, and a judgment matrix is constructed. The scale meaning of the judgment matrix is shown in TABLE Ⅱ.

TABLE II. SCALE MEANING of JUDGMENT MATRIX

Scale	*meaning*
1	Equally important
3	Slightly important
5	Generally important
7	very important
9	extremely important
2、4、6、8	Intermediate value

3)Calculate the Weight of Each Level

The weight of each factor's influence degree is further calculated according to the matrix A established in the previous step. The maximum eigenvalue λ_{max} and normalized maximum eigenvector $w=[w_1, w_2, ..., w_n]^T$ of matrix A are obtained. Therefore, it is only necessary to solve the maximum characteristic root: $Av = \lambda_{max} v$ then normalize W, and take the normalized characteristic vector as the weight of this influencing factor C1, C2, C3,..., Cn to the target influencing factor.

4)Consistency Inspection

It is the most direct and effective method to check the consistency of the matrix and measure the consistency of the paired comparison matrix by calculating the consistency index. If the CR value is less than or equal to 0.1, it indicates that the consistency of the comparison matrix is reasonable; However, if the CR value is above 0.1 and does not include 0.1, the comparison matrix needs to be further modified, $CI = (\lambda_{max} - m)/(m-1)$, $CR = CI / RI$ .Among them, RI value is an average random consistency index, involving a matrix of 1-11 orders in total. See TABLE Ⅲ for RI values of each order matrix.

TABLE III. RI VALUE

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

B. *Objective Weighting Evaluation Model Based on Entropy Weight Method*

Entropy Weight (EW) is a method to objectively determine weight coefficients. Entropy weight method is to describe the different degrees of evaluation indicators with entropy, and characterize the size of their weight coefficients according to the differences of evaluation indicators. The calculation steps of entropy weight method are as follows:

1)Construct Data Matrix

There are m evaluation objects and n evaluation indicators, and the original data matrix is A={aij} m × N (i=1,2..., m; j=1,2,..., n), aij is the jth index value of the ith evaluation object.

2)Construct Data Matrix

Entropy $c_j = -\frac{1}{\ln(m)} \sum_{i=1}^{m} p_{ij} \ln(p_{ij})$, where $\frac{1}{\ln(m)} > 0$and cj>0.

3)Calculate Difference Coefficient

Difference coefficient $d_j = 1 - c_j$ 。 For the entropy value and difference coefficient of the jth index, the smaller the entropy value, the greater the difference coefficient, the greater the information covered by the index, and the greater the corresponding index weight.

4)Calculate entropy weight

Further calculate the weight of each evaluation index according to the entropy value, where the entropy weight of the jth index is $f_j = \frac{d_j}{\sum_{j=1}^{n} d_j}$。

C. *Combination Weighting Evaluation Model Based on AHP-EW*

AHP can effectively use the knowledge and experience of the evaluators themselves, but the calculated comprehensive evaluation results will be greatly affected by the subjective factors of the evaluators, such as the lack of knowledge of the evaluators; Although EW is supported by objective and perfect specific factual data, it does not consider the subjective factors of the evaluators. Therefore, AHP and EW are organically combined in this paper. This combined weight determination method of AHP and EW can not only consider the knowledge and experience of evaluators, but also objectively present the information value of evaluation index data when calculating the weight.

The comprehensive weight coefficient W is obtained by combining the subjective weight coefficient obtained through AHP with the objective weight coefficient obtained through $W_j = \alpha W_{1j} + \beta W_{2j}$ $(j = 1,2,\cdots,n)$, where α Is the subjective weight coefficient, β Is an objective weight coefficient, and W1j and W2j are subjective and objective weights.

IV. EMPIRICAL ANALYSIS

In this paper, ten electricity selling companies are selected to test the proposed comprehensive capacity evaluation model, which is represented by symbols A~J. Select five experts to score the comprehensive ability evaluation index and its importance, and select the average of the scoring results as the final score to calculate the weight.

A. *Calculation of Index Weight*

1)Analytic hierarchy process for weight calculation

According to the scale meaning of the judgment matrix shown in TABLE Ⅱ, let the experts fill in the questionnaire and compare the importance of two different influencing factors. For the comparison judgment matrix A-B of the weight of the construction criteria layer, the corresponding maximum eigenvalue and eigenvector are calculated, and the consistency is checked. The eigenvectors of the criterion layer are shown in TABLE Ⅳ.

TABLE IV. CHARACTERISTIC VECTOR OF CRITERIA LAYER

influencing factor	Service ability	Credit level	technical competence	Marketing ability	innovation ability
weight	0.3851	0.2847	0.1906	0.0912	0.0484

Through calculation, determine the maximum eigenvalue of matrix A-B λ max=5.415。In order to check the consistency of the judgment matrix, it is necessary to calculate the consistency index and the average random consistency index, where CI is 0.104 and CR is 0.093. Since CR＜0.1, the criterion level judgment matrix is a satisfactory consistency matrix.

Similarly, the judgment matrix of the scheme level is calculated and consistency test is conducted to obtain the weight of each influencing factor, and the final weight of each influencing factor is obtained through composite calculation. The subjective weight obtained by the analytic hierarchy process is shown in TABLE Ⅴ. The consistency test results of the scheme layer are 0.07, 0.097, 0.057, 0.086 and 0.091 respectively, which all pass the consistency test.

TABLE V. INDEX WEIGHTS BASED ON AHP

Index	C1	C2	C3	C4	C5
Weight	0.4358	0.2966	0.1473	0.0789	0.0414
Index	C6	C7	C8	C9	C10
Weight	0.4961	0.2263	0.1472	0.0918	0.0286
Index	C11	C12	C13	C14	C15
Weight	0.4537	0.278	0.1489	0.0784	0.041
Index	C16	C17	C18	C19	C20
Weight	0.3372	0.278	0.17	0.1226	0.0613
Index	C21	C22	C23	C24	C25
Weight	0.0309	0.4591	0.3135	0.1566	0.0701

2)Calculation of weight by entropy weight method

According to the above calculation steps of entropy weight method, combined with the expert scoring results, the entropy weight results of each index are shown in TABLE Ⅵ.

TABLE VI. INDEX WEIGHTS BASED ON EWS

Index	C1	C2	C3	C4	C5
Entropy weight	0.011365	0.009978	0.019549	0.024117	0.030067
Index	C6	C7	C8	C9	C10
Entropy weight	0.021857	0.12794	0.060275	0.018507	0.011222
Index	C11	C12	C13	C14	C15
Entropy weight	0.022392	0.051115	0.035598	0.024332	0.029333
Index	C16	C17	C18	C19	C20
Entropy weight	0.037841	0.012616	0.023129	0.035337	0.051341
Index	C21	C22	C23	C24	C25
Entropy weight	0.040039	0.037437	0.084595	0.103615	0.076403

3)Calculation of weight by entropy weight method

According to the calculation steps of the combination weighting method, combine the weights obtained by the analytic hierarchy process with the weights obtained by the entropy weighting method, and calculate the weight coefficients of the subjective weighting method α 0.4416, weight coefficient of objective weighting method β Is 0.5584, and the final weight of the index obtained is shown in TABLE Ⅶ.

TABLE VII. WEIGHTS OF COMBINED WEIGHTING INDICATORS BASED ON AHP-EW

Index	C1	C2	C3	C4	C5
Combination weight	0.0814	0.0558	0.0328	0.0411	0.0291
Index	C6	C7	C8	C9	C10
Combination weight	0.0675	0.1014	0.0409	0.0149	0.0056
Index	C11	C12	C13	C14	C15
Combination weight	0.0539	0.0523	0.0194	0.0237	0.0267
Index	C16	C17	C18	C19	C20
Combination weight	0.0280	0.0217	0.0123	0.0349	0.0276
Index	C21	C22	C23	C24	C25
Combination weight	0.0280	0.0254	0.0920	0.0550	0.0273

B. Evaluation Results of Comprehensive Capacity of Power Sales Company

Based on the weight of scoring and indicators, the comprehensive score of evaluation objectives is obtained, so as to rank the comprehensive capabilities of different power selling companies. The calculation results of comprehensive scores are shown in TABLE Ⅷ.

TABLE VIII. SCORES OF COMPREHENSIVE CAPACITY OF POWER SELLING COMPANIES

Electricity selling company	Comprehensive score
A	63.0671
B	56.0824
C	57.5565
D	57.7637
E	51.7857
F	52.5296
G	54.2132
H	58.9047
I	58.0858
J	56.5286

C. Result Analysis

According to the calculation results of the comprehensive weight in TABLE Ⅶ, it can be seen that the completeness of qualification certificates, the number of patents and technologies and user satisfaction have a great impact on the comprehensive capacity of the power selling company, which should be focused on by the power selling company; However, corporate credit, user responsiveness and timeliness of contract settlement have little impact on the comprehensive capacity of the power selling company, which can reduce investment; Other indicators, such as risk control ability and market development ability, have a relatively large impact on the power selling company and can be used as the main investment direction of the power selling company.

TABLE Ⅷ shows the evaluation results of the comprehensive capacity of the power selling company. It can be seen that the comprehensive capacity of power selling company A has the highest score and is more popular with power users in the power market. The comprehensive score of H and I electricity selling companies is closely followed by that of users, who are also the key targets for electricity trading. Other power selling companies, such as E and F, have low comprehensive scores, so they need to focus on developing their own comprehensive capabilities in the future development, and the comprehensive weight of indicators also provides a direction for the development of these companies.

V. CONCLUSION

In this paper, the combined weighting method is used to evaluate the comprehensive capacity of the power sales company. First, the subjective and objective weights of each index are calculated by the analytic hierarchy process and entropy weight method, and the combined weights of all indexes are calculated according to the corresponding weight coefficients. Secondly, the comprehensive score of each electricity selling company is calculated according to expert scoring and index weight. Finally, according to the index weight and the score of the power selling company, the analysis points out the future development direction of the power selling company, such as the power selling company's investment in improving customer satisfaction is higher than the risk control ability. The comprehensive score result of the power selling company not only provides the basis for users to choose the power company, but also helps the power selling company to recognize its shortcomings and provide the direction for the future long-term development.

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